B.Tech Thesis on

ECONOMIC LOAD DISPATCH FOR IEEE 30-BUS SYSTEM USING PSO

For the partial fulfilment of the requirement for the degree of

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In

Electrical Engineering

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We are indebted to our friends and family who have always inspired to follow our passions and instilled in us a love for science and languages, all of which is reflected in this thesis.

We are thankful to almighty God for giving us courage to take up this project and complete it in time.

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CERTIFICATE

This is to certify that the Thesis Report entitled "**ECONOMIC LOAD DISPATCH IN IEEE 30-BUS SYSTEM USING PSO",** submitted by Ms BARNIKA SAHA bearing roll no. 111EE0229 and Mr SURAJ KUMAR RATH bearing roll no. 111EE0226 in partial fulfilment of the requirements for the award of Bachelor of Technology in Electrical Engineering during session 2011-2015 at National Institute of Technology, Rourkela is an authentic work carried out by him/her under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

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ABSTRACT:

ELD or economic load dispatch is a crucial aspect in any practical power network. Economic load dispatch is the technique whereby the active power outputs are allocated to generator units in the most cost-effective way in compliance with all constraints of the network. The traditional methods for solving ELD include Lambda-Iterative Technique, Newton-Raphson Method, Gradient method, etc. All these traditional algorithms need the incremental fuel cost curves of the generators to be increasing monotonically or piece-wise linear. But in practice the input-output characteristics of a generator are highly non-linear leading to a challenging non-convex optimisation problem. Methods like artificial intelligence, DP (dynamic programming), GA (genetic algorithms), and PSO (particle swarm optimisation) solve non-convex optimisation problems in an efficient manner and obtain a fast and near global and optimum solution. In this project ELD problem has been solved using Lambda-Iterative technique, GA (Genetic Algorithms) and PSO (Particle Swarm Optimisation) and the results have been compared. All the analyses have been made in MATLAB environment.

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CHAPTER 1

1.1 INTRODUCTION:

Engineers are always concerned with the cost of products and services. Minimising the operating cost is very important in all practical power systems. Economic load dispatch is the technique in which active power outputs are allocated to committed generator units with the aim of minimising generation cost in compliance with all constraints of the network. The traditional methods include Lambda-Iterative technique, Newton-Raphson Method, Gradient Method, etc. But these conventional methods need linear incremental cost curves for the generators. In practice the input-output curves of generators are discrete and non-linear due to ramp-rate limits, multiple fuel effects and restricted zones of operation.

The complex ELD problem needs to be solved by modern heuristic or probabilistic search optimisation techniques like DP (dynamic programming), GA (genetic algorithms), AI (artificial intelligence) and particle swarm optimisation. EP exhibits robustness, but sometimes shows slow convergence near the optimum point. GA is a probabilistic algorithm. GA comes out as a better algorithm owing to its parallel search approach which offers global optimisation.

Particle Swarm Optimisation was introduced by James Kennedy and Russell Eberhart. It solves non-linear hard optimisation problems. It was inspired by animal social behaviour like schooling in fishes, flocking of birds, etc. This technique operates without requiring information about the gradient of objective function or error function and it easily obtains the independent best solution. PSO technique provides high quality solution in less time and shows fast convergence.

In this report, IEEE 30-bus System is considered. Economic scheduling of six generators is done using Lambda Iteration method, GA (Genetic Algorithm) and PSO (Particle Swarm Optimisation) and at the end the fuel costs in all the three cases are compared. All the analyses are performed in MATLAB software.

1.2 PROJECT MOTIVATION:

Revenue loss is a major issue for any country. Conversion of this loss into utilisation would prove to be a huge benefit to the country. Our society wants secure supply of electricity at minimum cost with the least level of pollution in the environment. Through the years many researchers have put forth their ideas to minimise fuel cost and to reduce pollution. Out of the total generation of electricity in India, thermal power plants contribute around 80-85% of the power generation. In view of this fact, the economic load dispatch problem draws much attention. Substantial reduction in fuel cost could be obtained by the application of modern heuristic optimisation techniques for scheduling of the committed generator units.

1.3. LITERATURE REVIEW:

J.H.Park, I.K.Eong, Y.S. Kin, and K.Y.Lee [1] proposed Hopfield (neural network) method. Hopfield method solved the ELD problem with the cost function represented as a piecewise quadratic function instead of convex function. It is suitable for large number of generators. The advantage of real time response favours application of hardware.

Po-Hung and Hong-Chan Chang [2] applied genetic algorithms to solve the economic load dispatch problem. In case of dispatch on a large scale GA solution time increases with the increase in generator units. This algorithm can be used worldwide. Owing to its flexibility it can deal with ramp-rate limits, restricted zones of operation and losses in the network.

Zee-Lee Gaing [3] used PSO to solve ELD. It considers the non-linear characteristics of the generators. The feasibility of PSO was checked and it was found to be superior to Genetic Algorithms. PSO gives high quality solutions, computational efficiency and better characteristics of convergence.

T. A. Albert Victoire, A. E. Jeyakumar [4] combined PSO (particle swarm optimisation) and SQP (sequential quadratic programming) to solve the economic load dispatch (ELD) problem. PSO acts as the main optimiser and SQP adjusts the refinement in every solution of the PSO. SQP is a non-linear programming technique used to solve constrained optimisation problem. It showed high efficiency and accuracy. The property of convergence is not strained; it depends on incremental-cost-function. The combination PSO-SQP offers fast convergence characteristics and high quality solutions. This method is more practical as it can be employed in prohibited zone and with the consideration of network losses and valve-point effects.

Authors Yi Da, and G. Xiurun [5] proposed SA (simulated annealing) to improve PSO. They introduced the idea of SAPSO-based-ANN. Three-layer feed-forward neural network was employed. It consists of one hidden, one input and one output layer. SAPSO-based ANN proved to be superior to PSO-based ANN. Owing to its flexibility it was employed to solve many other problems.

1.4 THESIS ORGANISATION:

Chapter 2 illustrates the economic load dispatch problem in a thermal power plant. It explains why only the thermal power plants contribute to the ELD problem rather than hydro power plant or nuclear power plant. The system constraints i.e. equality and non-equality constraints are also described in this chapter.

Chapter 3 explains the ELD problem with traditional/ conventional Lambda Iterative technique. It describes the Lambda Iteration method without transmission loss as well as with transmission loss. The algorithms for ELD by lambda iteration are stated.

Chapter 4 describes the modern heuristic optimisation techniques of GA (genetic algorithm) and PSO (particle swarm optimisation). It elaborates the ELD solution with GA and PSO. The flow charts for both the techniques are also described.

Chapter 5 explains the results obtained in the ELD for IEEE 30 Bus system applying all the three methods of Lambda Iteration, GA (Genetic Algorithms) and PSO (Particle Swarm Optimisation). The economic scheduling of generators and the total generating cost for all the three cases are compared. All the analyses are performed in MATLAB environment.

CHAPTER 2

2.1 COST OF OPERATING GENERATOR:

Generators can be categorised as: nuclear, hydro and fossil (coal, oil or gas). Nuclear power plants tend to operate at output levels which are constant. For hydro-stations, the storage of energy is free apparently and so the operating cost does not infer any meaning. So only the cost of fuel burnt in fossil plants contributes to the dispatching procedure. The cost of operation of generator includes fuel, labour and cost of maintenance. Labour cost, costs of supplies and maintenance are not charged since these are a fixed percentage of incoming fuel cost. So only the fuel cost needs to be considered. Figure shows a simple model of thermal power plant.

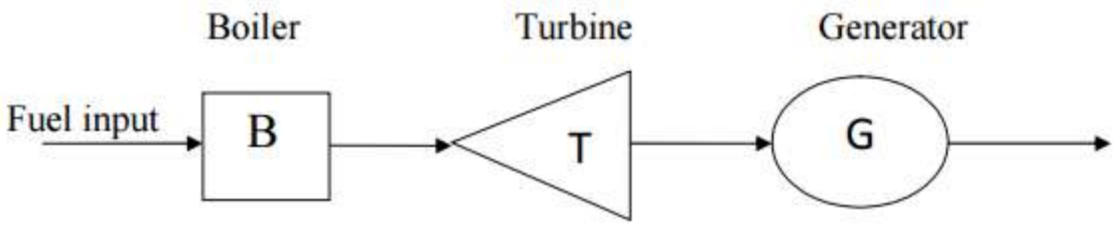

FIGURE 2.1: SCHEMATIC DIAGRAM OF A THERMAL PLANT.

The input in a thermal power plant is expressed in Btu/h. Active power output is expressed in MW. In fossil plants the power output is increased sequentially by opening the valves at the inlet of steam-turbine. When a valve is just open, the throttling losses are large and when it is fully opened, throttling losses are small. The fuel cost curve is modelled as a quadratic function of real power or active power. The fuel-cost curve as a function of active power takes the form:

$$F(P_{Gi}) = a_i * P_{Gi}^2 + b_i * P_{Gi} + d_i \quad \text{\$/hr.}$$

Here, F= Fuel cost.

P_{Gi} = Active power output of ith generator.

a_i , b_i & d_i denote constants of generator.

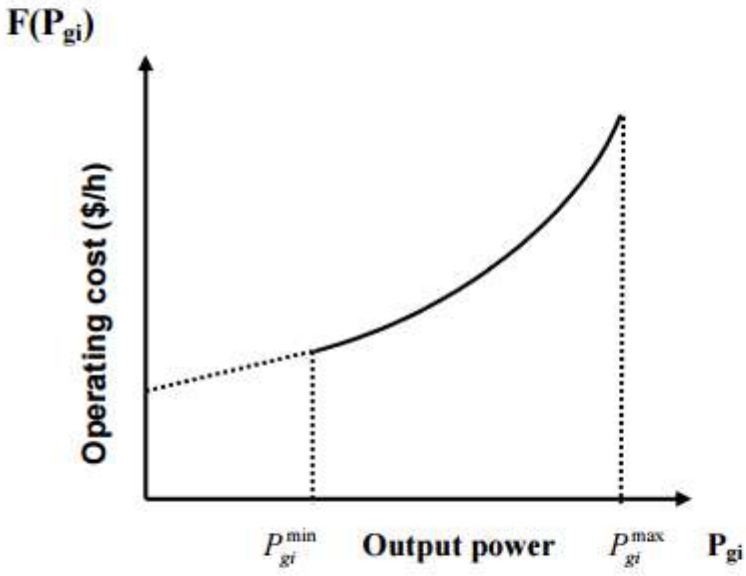

FIGURE 2.2: IDEAL FUEL COST CHARACTERISTIC.

The ideal fuel cost curve is a monotonically increasing convex function. But in practice fuel cost curve has many discontinuities owing to extra boilers, steam condensers or other equipments. P_{Gi}^{max} and P_{Gi}^{min} are the maximum and minimum limits on real power generation of the committed units. The incremental fuel cost is expressed by piece-wise linearization in the range of continuity.

2.2 SYSTEM CONSTRAINTS

Two types of constraints exist:

1. Equality Constraints
2. Inequality Constraints.

2.2.1 EQUALITY CONSTRAINTS:

Equality constraints are the basic power balance equations in compliance with the fact that total generation equals total demand minus transmission losses.

$$\sum_{i=1}^{N} P_G - P_D - P_L = 0. \tag{2.1}$$

2.2.2 INEQUALITY CONSTRAINTS:

1. **Generator constraints:**

   The kVA loading of the generator $\sqrt{(P^2+Q^2)}$ must not exceed a preset thermal limit. The maximum real power generation is restricted by the thermal constraint so that rise in temperature remains within limits.

   $$P_{\min} \leq P \leq P_{max} \tag{2.2}$$

   The maximum value of reactive power generation is restricted by overheating of the rotor and the minimum limit is due to the machine's stability limit. So the generator reactive power should be within the range as stated by the inequality constraint:

   $$Q_{min} \leq Q \leq Q_{max} \tag{2.3}$$

2. **Constraints on voltage:**

   The values of voltage magnitude and phase angle at different nodes must be within a specific range. The power angle of transmission must lie between 30 degrees and 45 degrees to comply with transient stability. Higher the power angle, lower is the stability in case of faults. The lower limit of operating angle assures optimum use of transmission capability that is available.

   $$V_{Pmin} \leq V_P \leq V_{Pmax} \tag{2.4}$$

   $$\delta_{min} \leq \delta \leq \delta_{max}$$

3. **Running spare capacity constraints:**

   Apart from meeting the load demand and transmission losses, the total generation should be such that a minimum spare capacity is available. These constraints are needed to meet unpredicted extra load on the system.

4. **Transmission line constraints:**

   Thermal capacity of the transmission line circuit restricts real and reactive power flow in the circuit.

   $$C_P \leq C_{Pmax} \tag{2.5}$$

   C_{Pmax}= maximum loading capacity of the p_{th} line.

5. **Network security constraints:**

   In the event of an outage, be it a scheduled or a forced one, some constraints of the network are not complied with. The complication in the constraints is increased in the analysis of a large power system. One or more branches at a time are taken out to study the effect.

CHAPTER 3

3.1ECONOMIC DISPATCH NEGLECTING LOSSES:

Let there be a station with generators of number NG and the given power demand be P_D.The actual power generation P_{gi} is to be allocated to generators so that total cost of generation is minimised. The optimization problem can be addressed as below.

Minimizing $\mathrm{F}(P_{gi}) = \sum_{i=1}^{NG} F_i(P_{gi})$ (3.1a)

Subject to

i. The power balance equality

$$\sum_{i=1}^{NG}(P_{gi}) = P_D \tag{3.1b}$$

ii. Active power constraints

$$P^{min}{}_{gi} \leq P_{gi} \leq P^{max}{}_{gi} \tag{3.1c}$$

P_{gi} = active power output of ith generator

P_D = load demand

NG =total number of generators

$P^{min}{}_{gi}$= lower limit for active power

$P^{max}{}_{gi}$= higher limit for active power

$F_i(P_{gi})$ is cost function. It is expressed as a quadratic function of active power.

$$F_i(P_{gi}) = a_i P^2{}_{gi} + b_i P_{gi} + c_i \ \text{\$/h} \tag{3.2}$$

For minimizing (or maximizing) a function the Lagrange multiplier is used. Using this method,

$$\mathrm{L}(P_{gi}, \lambda) = F(P_{gi}) + \lambda(P_D - \sum_{i=1}^{NG} P_{gi}) \tag{3.3}$$

To minimise cost of generation,

$$\frac{\partial L(P_{gi},\lambda)}{\partial P_{gi}} = \frac{\partial F(P_{gi})}{\partial P_{gi}} - \lambda = 0 \tag{3.4}$$

and

$$\frac{\partial L(P_{gi},\lambda)}{\partial \lambda} = P_D - \sum_{i=1}^{NG} P_{gi} = 0 \qquad (3.5)$$

From equation (3.4)

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = \lambda \qquad (3.6)$$

Equality (3.6) is called the co-ordination equation. Referring to equation (3.2), incremental fuel cost becomes:

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = 2a_i P_{gi} + b_i \qquad (3.7)$$

Comparing eq (3.6) and eq (3.7), we get

$$2a_i P_{gi} + b_i = \lambda \qquad (3.8)$$

Arranging the equation, we get

$$P_{gi} = \frac{\lambda - b_i}{2a_i} \qquad (3.9)$$

If we put this value in Equation (3.5), we get

$$\sum_{i=1}^{NG} \frac{\lambda - b_i}{2a_i} = P_D$$

or

$$\lambda = \frac{P_D + \sum_{i=1}^{NG} \frac{b}{2a_i}}{\sum_{i=1}^{NG} \frac{1}{2a_i}} \qquad (3.10)$$

Hence, λ is found out with the help of Eq (3.10) and P_{Gi} is found using (3.9).

3.2 ECONOMIC LOAD DISPATCH CONSIDERING LOSSES IN TRANSMISSION

In case of power transmission for long distances, losses in transmission need to be considered to find out the economic scheduling of generators.

Mathematical statement:

Minimise

$$F(P_{gi}) = \sum_{i=1}^{NG} a_i P^2{}_{gi} + b_i P_{gi} + c_i \text{ \$ /h} \qquad (3.11)$$

Subject to

i. power balance equality

$$\sum_{i=1}^{NG}(P_{gi}) = P_D + P_L \tag{3.11a}$$

ii. active power generation constraint

$$P^{min}{}_{gi} \le P_{gi} \le P^{max}{}_{gi} \tag{3.11b}$$

Transmission loss is expressed as a function of generated power with the help of B-coefficients. The formula for transmission loss in terms of B-coefficients is

$$P_L = \sum_{i=1}^{NG}\sum_{i=1}^{NG} P_{gi}B_{ij}P_{gi} \text{ MW} \tag{3.12}$$

P_{gi}, P_{gj} = real power outputs at the i^{th} and j^{th} buses.

B_{ij} = transmission loss coefficient.

NG= total number of generators.

Eq. (3.12) expressing transmission loss is George's formula.

Kron's loss formula, which is another form of transmission loss is expressed as the following

$$P_L = B_{00} + \sum_{i=1}^{NG} B_{i0}P_{gi} + \sum_{i=1}^{NG}\sum_{i=1}^{NG} P_{gi}B_{ij}P_{gj} \text{ MW} \tag{3.13}$$

Where

P_{gi}, P_{gj} = active power outputs at the i^{th} and j^{th} buses.

B_{ij} = transmission loss coefficients.

NG= total number of generators.

So constrained problem now reduces to unconstrained problem of optimisation.

$$L(P_{gi}, \lambda) = F(P_{gi}) + \lambda\left(P_D + P_L - \sum_{i=1}^{NG} P_{gi}\right) \tag{3.14}$$

For optimization,

$$\frac{\partial L(P_{gi})}{\partial P_{gi}} = \frac{\partial F(P_{gi})}{\partial P_{gi}} + \lambda\left(\frac{\partial P_L}{\partial P_{gi}} - 1\right) = 0$$

$$\frac{\partial F(P_{gi})}{\partial P_{gi}} = \lambda\left(1 - \frac{\partial P_L}{\partial P_{gi}}\right) \tag{3.15}$$

Where

$\frac{\partial F(P_{gi})}{\partial P_{gi}}$ = incremental cost for i^{th} generator

$\frac{\partial P_L}{\partial P_{gi}}$ = incremental transmission loss

Moreover,

$$\frac{\partial(P_{gi},\lambda)}{\partial \lambda} = P_D + P_L - \sum_{i=1}^{NG} P_{gi} = 0 \tag{3.16}$$

Transmission loss equality is differentiated with respect to P_{gi}, to obtain incremental transmission loss

$$\frac{\partial P_L}{\partial P_{gi}} = B_{i0} + \sum_{i=1}^{NG} 2B_{ij}P_{gj} \qquad (i = 1,2,3,\ldots\ldots, NG) \tag{3.17}$$

The cost function is differentiated with respect to $P_{gi}$to obtain incremental fuel cost

$$\frac{\partial y}{\partial x} = 2a_iP_{gi} + b_i \qquad (i = 1,2,3,\ldots\ldots, NG) \tag{3.18}$$

Equality (3.15) becomes

$$\frac{\frac{\partial F(P_{gi})}{\partial P_{gi}}}{1-\frac{\partial P_L}{\partial P_{gi}}} = \lambda$$

Or $$\left(\frac{\partial F(P_{gi})}{\partial P_{gi}}\right) L_i = \lambda \tag{3.19}$$

Here, $L_i = \frac{1}{1-\frac{\partial P_L}{\partial P_{gi}}}$ is penalty factor for i^{th} generator.

Substituting Eq. (3.17) & (3.18) in Eq.(3.15),we get

$$2a_iP_{gi} + b_i = \lambda\big(1 - B_{i0} - \textstyle\sum_{j=1,}^{NG} 2B_{ij}P_{gj}\big) \qquad (3.20)$$

$$2(a_i + \lambda B_{ii})P_{gi} = \lambda\big(1 - B_{i0} - \textstyle\sum_{j=1, j\neq i}^{NG} 2B_{ij}P_{gj}\big) - b_i \qquad (i = 1,2,3, \ldots\ldots, NG)$$

So P_{gi} is expressed as

$$P_{gi} = \frac{\lambda\big(1 - B_{i0} - \sum_{j=1, j\neq i}^{NG} 2B_{ij}P_{gj}\big) - b_i}{2(a_i + \lambda B_{ii})} \qquad (3.21)$$

3.3 SEQUENCE OF STEPS FOR ELD

1. Input data is fed i.e. generator constants $a_{i,} b_i, c_i$; B-coefficients,B_{ij}, B_{i0} ; tolerance of convergence ε; step size α; and maximum number of iterations, ITMAX, etc.
2. Initial values of P_{gi} and λ are evaluated without considering losses i.e. P_L=0. The equations (3.1a) and (3.1b) define the problem.
3. Iteration counter is set at IT=1
4. P_{gi} is evaluated using the equality

   $$P_{gi} = \frac{\lambda\big(1 - B_{i0} - \sum_{j=1}^{NG} 2B_{ij}P_{gj}\big) - b_i}{2(a_i + \lambda B_{ii})} \qquad (i = 1,2,3, \ldots\ldots, NG)$$
5. The transmission loss is found out using Eq.(3.13)
6. Calculate $\Delta P = P_D + P_L - \sum_{i=1}^{NG} P_{gi}$
7. Verify whether $|\varDelta P| \leq \varepsilon$.If 'yes', go to 10th step. Verify whether IT ≥ ITMAX. In case it is so, 10th step is used.
8. Make $\lambda^{new} = \lambda + \alpha\varDelta P$
9. Update IT = IT + 1=λ^{new},go to 4th step. The cycle is repeated again.
10. Compute optimised minimum cost of generation from Eq. (3.11) & transmission loss in the line from Eq. (3.16).
11. End.

3.4 SEQUENCE OF STEPS FOR ELD IN VIEW OF LIMITS

1. Input data is fed i.e. generator constants, $a_{i,} b_i, c_i$; B-coefficients,B_{ij}, B_{i0}, B_{00} ; tolerance of convergence ε; size of step α;and maximum number of iterations ITMAX, etc.
2. Initial values of P_{gi} and λ are evaluated without considering losses i.e. P_L=0. The equations (3.1a) and (3.1b) define the problem.
3. It is assumed that none of the generators is at lower bound or upper bound.
4. The counter of iteration is set at IT=1
5. Calculate P_{gi} using the equation

   $$P_{gi} = \frac{\lambda\left(1-B_{i0}-\sum_{j=1}^{NG} 2B_{ij}P_{gj}\right)-b_i}{2(a_i+\lambda B_{ii})} \qquad (i = 1,2,3, \ldots\ldots, NG)$$
6. The transmission loss is found out with the help of Eq.(3.13)
7. Calculate $\Delta P = P_D + P_L - \sum_{i=1}^{NG} P_{gi}$
8. Verify whether $|\Delta P| \leq \varepsilon$.If 'yes', go to 11th step. Verify whether IT ≥ ITMAX. In case it is so, 11th step is used.
9. Make $\lambda^{new} = \lambda + \alpha \Delta P$
10. Update IT = IT + 1=λ^{new}, go to 4th step. Repeat the cycle.
11. The limits are verified for generators, in case no violations occur, proceed to 13th step or else continue.

    If $P_{gi} \leq P_{gi}^{min}$, $P_{gi} = P_{gi}^{min}$

    If $P_{gi} \geq P_{gi}^{max}$, $P_{gi} = P_{gi}^{max}$
12. Jump to 4th step.
13. Compute the optimised minimum cost of generation from Eq. (3.11a) and network loss from Eq. (3.16).
14. End

CHAPTER 4

4.1 GENETIC ALGORITHMS

4.4.1 Concept of Genetic Algorithms:

Genetic algorithms are search heuristics which mimic the process of natural selection in genetics. It is based on Charles Darwin's concept of "Survival of the fittest". Living beings compete for the scanty resources available in nature; the fittest individuals survive better and dominate over the weaker ones. Holland first proposed the concept of GA (genetic algorithms).

Genetic Algorithms mimic the mechanism of natural selection. In GA every chromosome is regarded as a potential solution for optimisation. The parameters to be optimised in the problem are the genes of a chromosome and it is more like a binary string. Every chromosome in the overall populace is assigned a fitness value. A fitter chromosome produces high-quality-offspring, which corresponds to a superior solution to optimisation. In GA design variables are equivalent to strings of binary variables; GA is applicable to discrete and integer programming problems. A set of chromosomes called the "parents" or "mating pool" are chosen by a particular selection-routine; their genes are mixed and recombined to produce offspring in the subsequent generation. In GA cycle, Roulette Wheel selection and the two operators of genetics i.e. crossover and mutation are used. The evolution cycle continues until a desired stopping criterion is reached or maximum iterations have been performed.

4.1.2 GENETIC OPERATORS

a) Reproduction:

Reproduction is a genetic operator by virtue of which an old chromosome, based on its fitness value, is copied into a Mating pool. Fitter chromosomes correspond to greater number of copies in the coming generation. The chromosomes which score high in fitness value are more probable of contributing offspring in the subsequent generation. In reproduction the new offspring replaces the chromosome possessing the smallest value of fitness in the population if a number randomly generated between 0 and 1 is smaller than p_a or the probability of acceptance which is user defined.

b) Crossover:

A point of crossover is selected at random. The portions of two chromosomes beyond this cut off point are exchanged. A rate of operation (Pc) with a typical value of 0.6 to 1 is taken as the crossover probability. Crossover is a recombination operation. Crossover operation may be of three types: single point crossover, multi point crossover and uniform crossover.

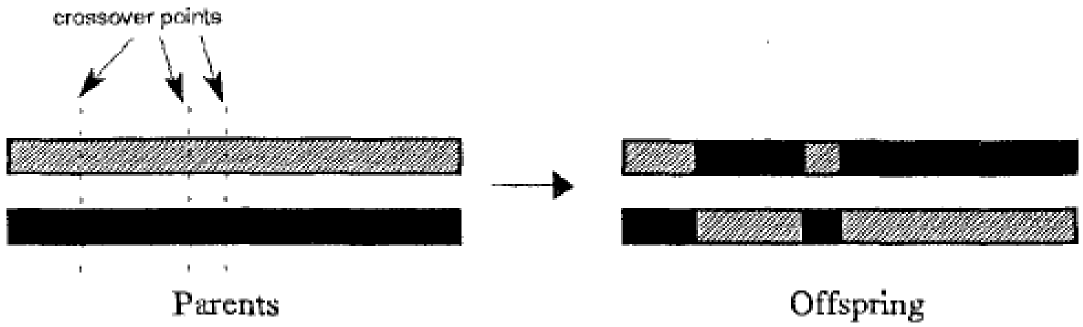

FIGURE 4.1 MULTIPLE POINT CROSSOVER

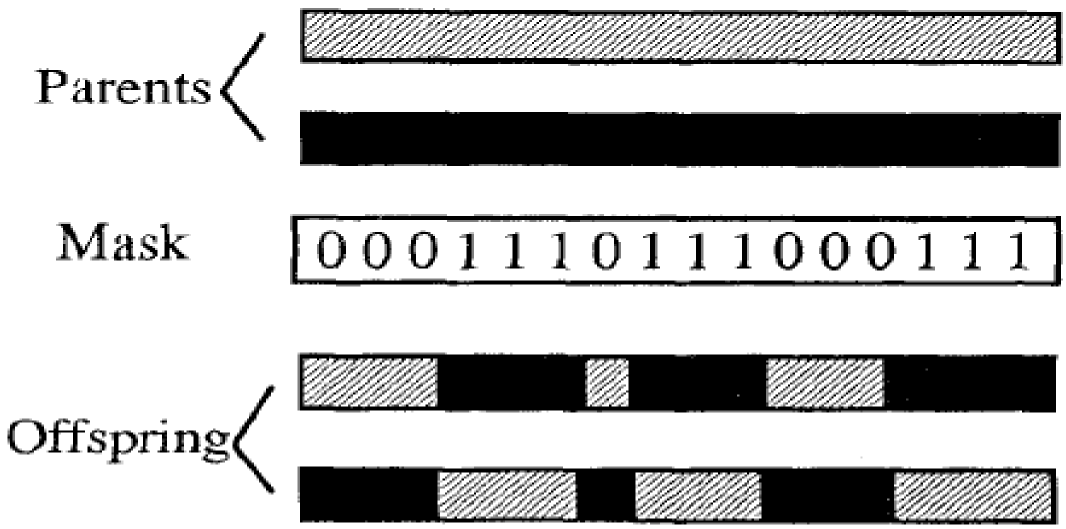

FIGURE 4.2 UNIFORM CROSSOVER

c) Mutation:

Mutation is performed in each new individual after the crossover operation is completed. It alters each bit of the chromosome at random with probability Pm, having a value of generally less than 0.1. Mutation operation alters the genes of the chromosomes. The mutation operation can be realised by applying various techniques like boundary mutation, uniform mutation or non-uniform mutation. In boundary mutation a gene is randomly selected and its value is changed to its upper or lower bound value. In uniform mutation a gene is selected randomly and its value is altered to a value between its upper and lower bounds. In non-uniform mutation the value of a random gene is increased or decreased by a weighted random number i.e. fine tuning is possible.

4.1.3 ROULETTE WHEEL PARENT SELECTION:

1. Total fitness (N) i.e. addendum of the fitness values of all members present in the population is evaluated.

2. A number (n) is generated at random between 0 and N.

3. The first member of the population, whose fitness when added to the fitness of preceding populace members exceeds n, is returned.

4.1.4. ELITISM:

A practical variant of the general procedure of creating a new populace is to let the fittest organism(s) from the present generation to be passed on to the next, unaltered. Such an approach is known as elitist selection. It ensures that the quality of solution will not degrade from one generation to the next. The probability that a chromosome will be selected for elitism is the probability of elitism, denoted by Pe. This states the percentage or fraction of the total number of parents that are directly copied into the next generation. Elitism ensures that the best or fittest strings are not lost by directly copying them into the next generation.

4.1.4 FLOW CHART FOR GENETIC ALGORITHM:

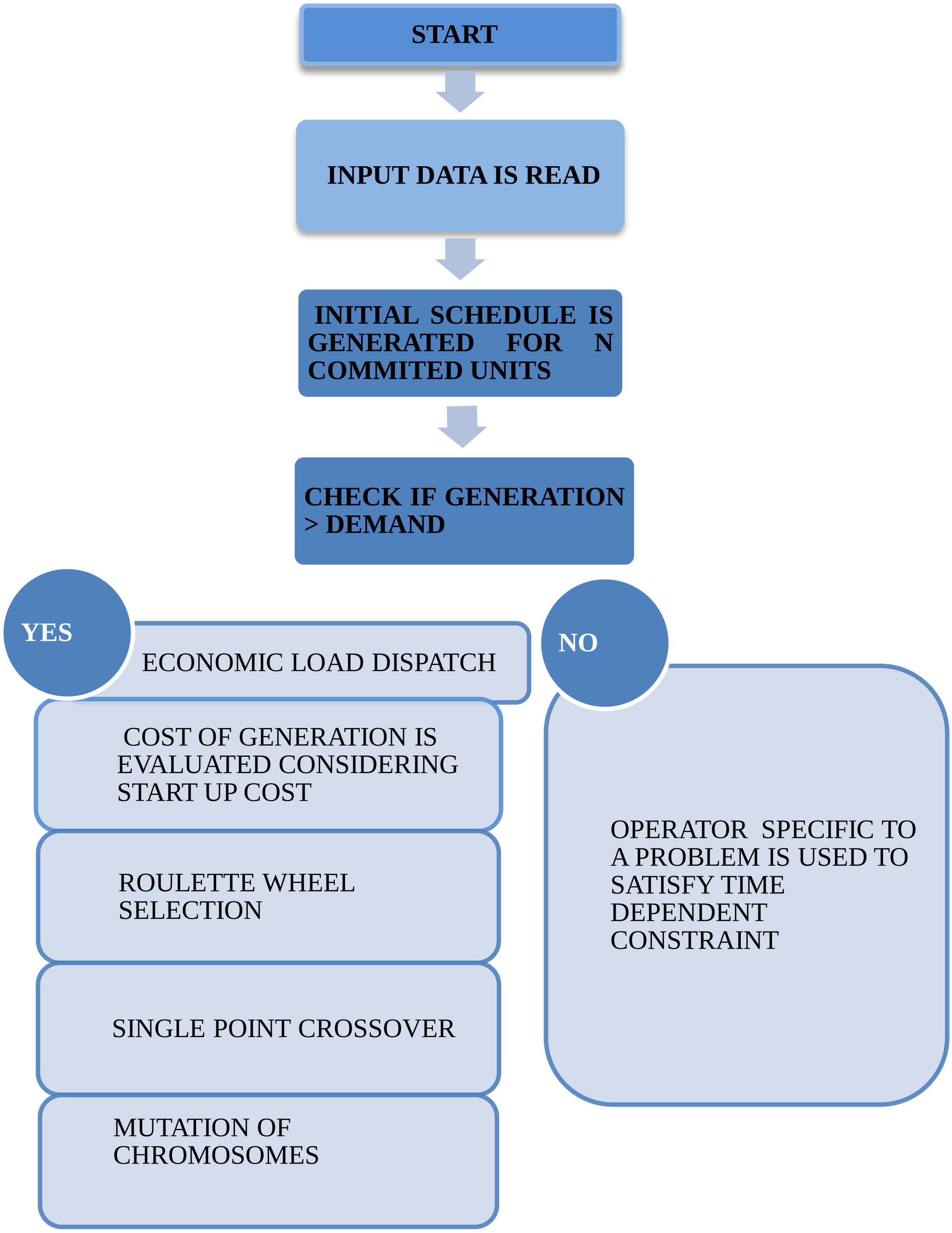

FIGURE 4.3 FLOW DIAGRAM FOR GA.

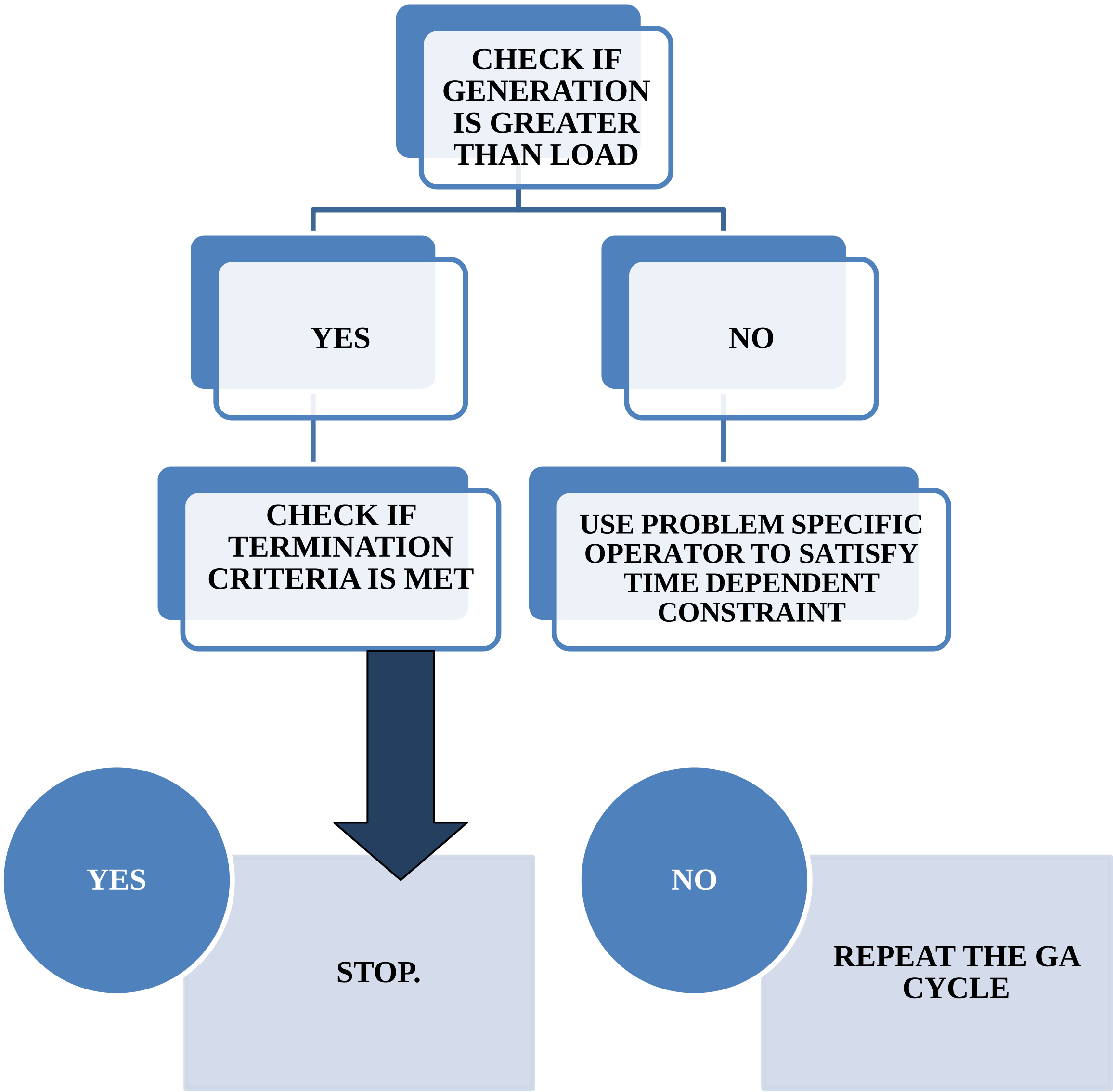

FIGURE 4.4 STOPPING CRITERION FOR GA.

4.2 PARTICLE SWARM OPTIMISATION

4.2.1 Concept of PSO:

Particle swarm optimisation, introduced by Kennedy and Eberhart in the year 1995, is a population-based, heuristic search optimisation technique conceptualised by a variety of animal social behaviour like flocking of birds and schooling of fishes, etc. In accordance with PSO system, particles move about in a search space which is multi-dimensional. A particle, as time passes through its quest, updates its position based on self-experience and that of its neighbouring particles, in view of the best position encountered by it and its neighbours. Each individual in PSO flies in the multidimensional search space with a velocity which is dynamically adjusted based on the flying experience of self and experience of its companions.

Let X and V symbolise the position and velocity of the particle in the search space. Each i^{th} particle is expressed as X_i= ($X_{i1}, X_{i2,} X_{i3}, \ldots \ldots X_{id}$) in the space of d-dimension. The i^{th} particle keeps track of the best previous position expressed as $pbest_i$= ($pbest_{i1}$,$pbest_{i2}, pbest_{i3}, \ldots \ldots pbest_{id}$) . The index of particle which is best among all the particles in multi-dimensional search space is the global best particle, denoted as $gbest_d$. The modified position and velocity of every particle are computed based on the current velocity and distance from $pbest_{id}$ and $gbest_d$, which can be expressed as follows.

$$V_{id}^{(t+1)} = w * V_i^t + c1 * \text{rand}() * (pbest_{id} - P_{gid}^t) + c2 * \text{rand}() * (gbest_{id} - P_{gid}^t). \quad (4.1)$$

$$P_{gid}^{(t+1)} = P_{gid}^t + V_{id}^{(t+1)}. \quad (4.2)$$

The velocity of the i^{th} particle must satisfy:

$$V_d^{min} \leq V_{id}^t \leq V_d^{max}. \quad (4.3)$$

The value V_d^{max} determines clearly the resolution with which search space should be searched between target position and present position. If V_d^{max} is too high, particles may fly past good solutions. If V_d^{max} is too small, particles may not explore in a sufficient manner beyond local solutions. The constants c1 and c2 pull every particle towards personal best (pbest) and global best (gbest) positions. The acceleration constants c1 and c2 are often set at 2.0 based on past experience. Inertia weight 'w' keeps a balance between local and global explorations.

Inertia weight factor “w” decreases linearly between 0.9 and 0.4 according to

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} * iter. \qquad (4.4)$$

w = inertia weight factor.

4.2.2 STEPS OF IMPLEMENTATION OF PSO IN ELD

The PSO algorithm is utilised to determine the optimum allocation of power among committed units to minimise the total generation cost. In PSO each particle is a potential solution for the ELD (economic load dispatch) problem. The particles are generated for each generating unit considering all the constraints.

The sequence of steps applied to solve the ELD problem using PSO is as follows.

1. The fitness function i.e. the reciprocal of the cost of generation is initialised.
2. The parameters of PSO i.e. c1, c2, population size, w_{max},w_{min}, error gradient, etc. are initialised.
3. Input data is fed, which includes cost functions, MW limits of generators, B-coefficient matrix and load-demand.
4. At the beginning of execution of the algorithm a large number of active power vectors which satisfy MW limits of generators are allocated at random.
5. The value of fitness function for each vector of active power is evaluated. The values which are obtained in a single iterative step are compared so as to decide pbest. All the fitness function values for the whole population are compared which decides the gbest. These pbest and gbest values are updated at each iterative step.
6. In each iteration the error gradient is checked and gbest is plotted till it comes within the pre-specified range.
7. The gbest value so obtained is the minimum cost. Active power vector determines the optimum ELD (economic load dispatch) solution.

4.2.3 FLOW CHART FOR PSO:

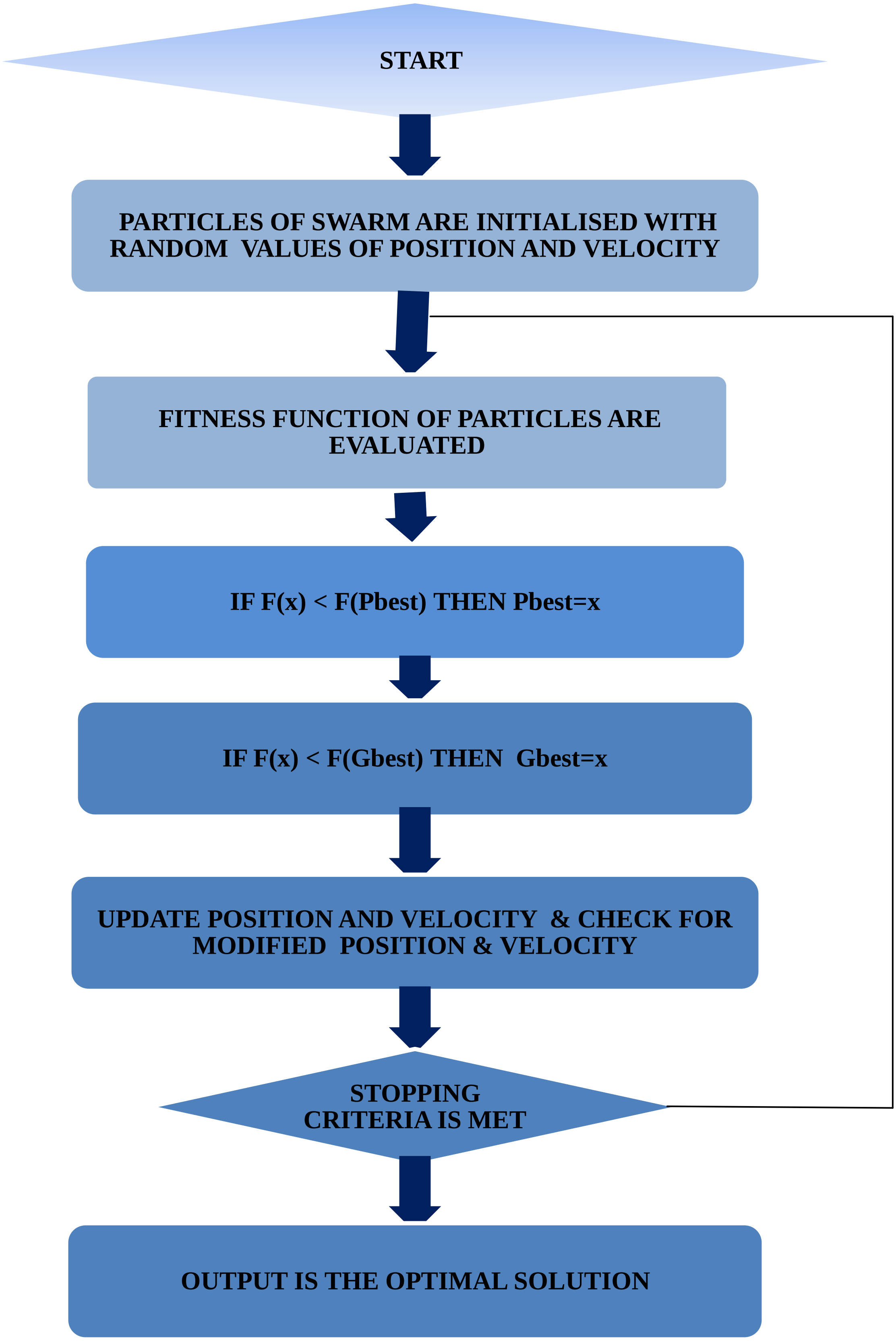

FIGURE 4.5 FLOW DIAGRAM FOR PSO.

4.2.4 ADVANTAGES OF PSO OVER GA:

The algorithm of PSO offers a variety of benefits like easy concept, simple execution, robustness to parameters of control and efficiency in computation.

Genetic algorithms have been applied quite efficiently to solve hard problems of optimisation. But research in recent times has revealed a number of drawbacks of GA. The breakdown in efficiency of GA is prominent in applications where objective functions are highly epistatic i.e. the parameters to be optimised are correlated highly. The genetic operators of crossover and mutation are unable to ensure better fitness or competitiveness of offspring owing to the fact that chromosomes that are present in the population have nearly close structures and the fitness on an average becomes high as the evolution cycle approaches the end. Apart from these, premature convergence in case of GA deteriorates its efficiency and decreases search capability which leads to greater probability of achieving local optimum.

PSO offers high quality solutions, limited time of computation and stable convergence.

4.2.5 DRAWBACK OF PSO:

PSO has got the disadvantage of getting caught up in local minimum while it handles heavy constraints in problems of optimisation due to restricted local or global search capabilities.

CHAPTER 5

RESULTS:

5.1 ECONOMIC LOAD DISPATCH USING LAMBDA ITERATION :

IEEE 30-bus system has 6 generators with active power outputs Pg1; Pg2…Pg6. Lambda iteration technique yields the following system results:

Total system loss= 9.55285 MW.

Incremental cost of delivered power = 3.642535 \$/h

TABLE NO. 5.1: Optimal dispatch of generation for Lambda Iteration

Generator unit	Pg1	Pg2	Pg3	Pg4	Pg5	Pg6
Active power output in Megawatts (MW)	176.9633	48.2707	20.9878	22.3787	12.3847	12.0000

Total cost of generation **= 802.63 \$/h.**

5.2 ECONOMIC LOAD DISPATCH IN IEEE 30-BUS SYSTEM USING GENETIC ALGORITHM:

TABLE NO. 5.2: Optimal dispatch of generation for GA

Generator unit	Pg1	Pg2	Pg3	Pg4	Pg5	Pg6
Active power output in MW	176.4562	49.1225	20.9848	22.1436	12.6509	11.4115

Total cost of generation=**801.8551 \$/h.**

5.3 ECONOMIC LOAD DISPATCH USING OF IEEE 30-BUS SYSTEM USING PARTICLE SWARM OPTIMISATION:

TABLE NO. 5.3: Optimal dispatch of generation for PSO

Generator unit	Pg1	Pg2	Pg3	Pg4	Pg5	Pg6
Active power output in MW	191.8163	48.2464	19.5090	11.3083	10.0000	12.0000

Total cost of generation= **799.9895 $/h.**

So the total cost of generation is the lowest in case of Particle Swarm Optimisation. The cost of generation obtained in case of genetic algorithms is lower than that of conventional Lambda Iterative technique. PSO achieves the most economical scheduling of generators with the least cost of operation. So PSO proves to be superior to Lambda iteration and GA techniques in solving the economic load dispatch problem.

Tables 5.1, 5.2 and 5.3 show the distribution of real power among the committed generator units for all the three iterative methods. Since PSO offers the lowest cost of generation, the generator scheduling in case of PSO is the most economic one.

CONVERGENCE CURVE FOR PSO:

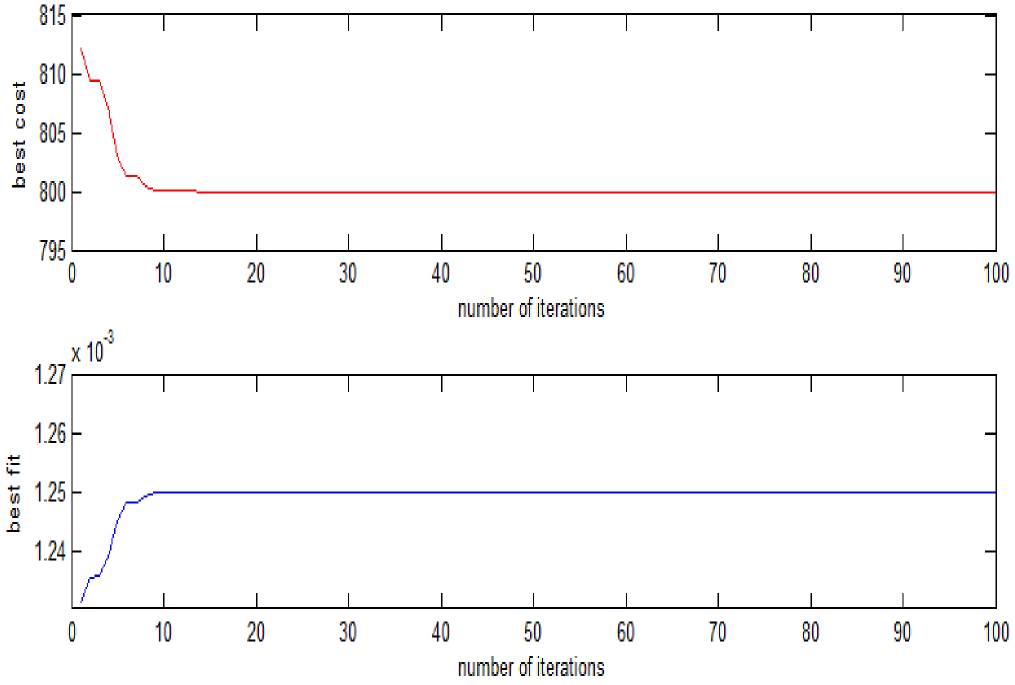

FIGURE 5.1: FITNESS FUNCTION CURVE

Figure 5.1 shows the convergence of PSO algorithm as the iterations proceed. The value of fitness function gradually increases as the number of generations or iterations increase. The fitness function is the reciprocal of cost function which decreases as the number of iterations increases. It is evident from the figure that PSO exhibits fast convergence.

CHAPTER 6

6.1 CONCLUSION:

In this report, three techniques (Lambda Iteration, Genetic Algorithm & PSO) have been applied to solve the ELD problem to compare the superiority among them. PSO showed high quality solution and stable convergence. The plotted graph for the IEEE 30-bus system showed the convergence characteristics. PSO (particle swarm optimisation) is superior in terms of reliable performance. The improved convergence in particle swarm optimisation (PSO) owes to the incorporation of inertia weight (w) factor whose value varies from 0.9 to 0.4. Lowest fuel cost i.e. most economic operation was obtained in case of PSO.

6.2 FUTURE SCOPE:

Many variants of particle swarm optimisation (PSO) have been introduced. These include techniques like PSO based ANN with simulated annealing technique, APSO (adaptive particle swarm optimisation), QPSO (quantum inspired particle swarm optimisation), HPSO etc. which are yet to be implemented in problems. The study of heterogeneity in PSO has to been done extensively. The efficiency of PSO can be enhanced by applying an advanced local minimiser.

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